

THE KICKER MAGNET OF THE CPS - FAST - EJECTION SYSTEM

1. Summary
2. Introduction
3. General Considerations
4. Construction
5. Monitoring and Interlocks
6. Tests
7. Measurements
8. First Results
9. Acknowledgements

## 1. Summary

In this report the kicker magnet of the C.P.S. fast ejection system is described, as well as its main parameters and the first results of its operation.

## 2. Introduction

To eject the proton beam from the CPS, a fast ejection system was built which permits the ejection of the whole beam conserving the RF structure, or a single bunch. The system consists of a so-called kicker magnet, an ejection magnet, their power supplies, monitoring, etc. The magnets are brought into position at the end of the acceleration cycle by means of hydraulic actuators. A layout of the system and the position of the magnets in respect to the CPS is shown in Fig. 1.

The whole system has already been described in other papers, Refs. 1 - 3. This report will only deal with the kicker magnet. The pulse generator, the monitoring, and interlock system are described in Refs. 4 and 5.

There are different ways to generate very fast-rising magnetic fields. For this magnet, a delay-line approach was chosen, as it has been described in Ref. 6.

Figure 2 gives the principle of the kicker magnet circuit. A pulse-forming network, a so-called storage line, is charged over a charging resistor to a certain voltage and discharged by means of a spark gap via the delay line kicker magnet into a terminating resistor. The triggering of the spark gap is initiated by an RF pulse, which is connected to the revolution frequency of the bunches, in the CPS. The pulse, which in our case is negative, has a duration  $T$  which is twice the delay time of the pulse-forming network, and its voltage is half the charging voltage.

The characteristic impedance of the kicker magnet circuit is  $10.4 \Omega$ . The storage lines, spark gaps, cables connections, the kicker magnet, and terminating resistors are adjusted to this value. The voltage for which the system

PS/4631

is designed is 100 kV on the storage lines, 50 kV on the kicker magnet. The magnetic flux density in the gap is  $0.18 \text{ Wb/m}^2$  at 70 kV on the storage lines. The rise-time of the magnetic field is  $0.07 \text{ } \mu\text{sec}$ . The pulse length is  $0.1 \text{ } \mu\text{sec}$  for the short and  $2.1 \text{ } \mu\text{sec}$  for the long and short storage lines. The C-shaped beam gap is 15 mm high and 25 mm wide. In order to clear the beam orbit at the beginning of the acceleration cycle, when the beam fills the whole vacuum chamber (elliptical shape  $70 \times 140$ ) a movable construction has been adopted.

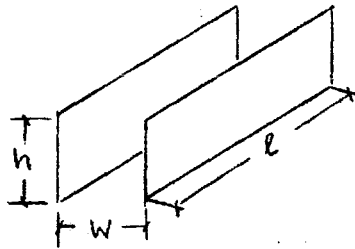
### 3. General Considerations

When starting the design of the fast ejection system, the aim was high efficiency, extreme cleanness and the possibility of ejecting one single bunch. To fulfil these requirements the rise- and in the case of the singl-bunch ejection, the decay-time of the magnetic field including the jitter must be smaller than the time interval between two subsequent bunches. For the CPS this interval is  $0.1 \text{ } \mu\text{sec}$ . This means that the greatest tolerable rise- and decay-time of the field has to be  $0.07 \text{ } \mu\text{sec}$  permitting some margin for jitter. For complete ejection the decay-time is of no importance.

The beam dimensions are determining the limits for the beam gap. The greatest mean beam diameter<sup>7)</sup>, of the lowest momentum for which the ejection system is designed, is 10 mm. Taking into account instabilities of the beam, and non-uniformity of the magnetic field of the kicker magnet in radial direction a gap height of 15 mm and width of 25 mm are sufficient. The minimum deflection of the beam at  $28 \text{ GeV/c}$  has to be  $1.1 \text{ mrad}$  in order to clear the septum of the ejection magnet. This determines for a given length of the available space of 0.9 m for the kicker magnet, the magnetic flux density, which has to be  $0.18 \text{ Wb/m}^2$ . With these parameters the limits are set for the design.

After a comparison of different possibilities considering the special purpose, the available space, etc., a kicker magnet of a delay-line type, a movable construction, and operation in vacuum seemed to be the most promising solution in spite of different complications which are involved.

The theory of a delay-line magnet has been treated in different papers. Here the main formulas should be recalled in order to discuss the choice for the different parameters of the kicker magnet. In a kicker magnet of the length  $l$ , divided into  $N$  units, which are pulsed parallel, the magnetic field in the beam gap can be considered as being equal to a field between two parallel, thin conductors of rectangular cross-section.



The inductivity for one unit is :-

$$L = \mu_0 \cdot \frac{l \cdot w}{N \cdot h} \quad (1)$$

and the flux  $\phi$  is given.

$$\phi = \mu_0 \cdot \frac{l \cdot w}{N \cdot h} \cdot J \quad (2)$$

or the flux density

$$B = \mu_0 \cdot \frac{J}{h} \quad (3)$$

For the kick which is defined as

$$K = \int_0^l B_y(z) \cdot dz \quad (4)$$

one gets for an arrangement as shown in the sketch above

$$K = \mu_0 \cdot J \cdot \frac{l}{h} \quad (5)$$

The delay time  $\tau$  is given by

$$\tau = \sqrt{L \cdot C} \quad (6)$$

and the characteristic impedance  $Z$  by

$$Z = \sqrt{\frac{L}{C}} \quad (7)$$

or

$$Z = \frac{L}{\tau} \quad (8)$$

The voltage on the kicker magnet, which is half of the charging voltage of the storage lines, is

$$V = J \cdot Z \quad (9)$$

or substituting  $J$  by Eq. (5) and  $Z$  by Eq. (8) one arrives at

$$V = \frac{K \cdot w}{\tau \cdot N} \quad (10)$$

As pointed out above, in our case the rise-time of the magnetic field, the dimensions of the beam gap, and the necessary deflection was given. From this, the other parameters are calculated.

The dependence of one of the most important parameters which influences the design of the whole circuit, the voltage, is given in Eq. (10). As can be seen, for a given kick, rise-time of the magnetic field and gap dimension, only the number of units is determining the voltage.

For the impedance  $Z$ , which is the characteristic impedance for the whole circuit one has to consider the availability of coaxial cables for the pulse transmission for the voltage in question.

The inductance  $L$  is mainly given by the dimensions of the beam gap and the number of units,

The matching capacitance  $C$  is distributed over the whole length of the kicker magnet unit. By putting a capacitor between each element the capacity is split up in  $n-1$  capacitors if  $n$  is the number of elements per kicker magnet unit. The number of elements might be chosen, but it

should be such that  $\tau$  for one element is small compared to the delay-time of the kicker magnet unit.

For the inductance  $L$  and the capacitance  $C$  the leakage inductance and the leakage capacitance has also to be considered. These two factors might be influenced by the design and it is clear they should be small. This applies particularly to the leakage inductance. The main parameters are given in Table 1.

### Construction

A sectional view of the kicker magnet in its vacuum tank is given in Figs. 3 and 4. The kicker magnet represents basically a ferrite-loaded, coaxial line with an opening for the beam gap so that it forms a C-magnet. It consists of two units which are mounted into a support. This support is fixed to a travel gear to allow the horizontal displacement. The connection to the hydraulic actuator is made by means of a hollow, on the outside high-polished steel shaft, which contains all cables for the kicker magnet, its monitoring, and interlocks. For the connection from the junction box to the shaft, highly flexible cables are used. The lead-through of the shaft in the vacuum tank is made by a special seal. For all components of the system, pulse generators, connections, leads and the kicker magnet, a coaxial construction is used, and conical, high-voltage connectors are used for all connections. A cross-section and a side view of a kicker-magnet unit is shown in Fig. 5.

As a first step, one might distinguish between the inner and outer conductor. The inner conductor consists of 18 single elements, wherein 16 are equal, the first and the last one being different for connection purposes. One of these connection elements has no ferrite ring. The former (its cross-section is shown in Fig. 5) is formed by two aluminium discs which are pressed together and covering the ferrite ring, screening it against the electrical field and keeping it at the potential of the inner conductor. The contact between the two discs is made on the inside

of the ferrite ring. On the outside they are insulated against each other. The current is flowing from the centre outwards to the edge, back around the ferrite ring and out to the edge of the second disc and back to the centre. The empty space between the two discs, the ferrite ring, and also 5 mm on the circumference are filled with epoxy resin under vacuum. Afterwards, the element is machined to its exact dimension. The thickness of the elements is determined by the thickness of the ferrite ring plus four times the skin depth of the current at this frequency in aluminium. The reason for the choice of the diameter will be given later.

The finished discs are placed in boxes made out of polyethylene which form the insulator. Polyethylene was chosen on account of its high electric strength and its shock resistance. The boxes were fabricated in moulds and particular care was taken to receive a homogeneous, tension-free piece. Figure 6 shows the aluminium-cladded ferrite ring in the open polyethylene box.

The connection elements are shown in Fig. 7. The element which contains the ferrite ring is similar to the 16 other elements, except for the outer diameter of the aluminium cladding which is smaller. The other element with the short connection pipe contains an aluminium disc in order to reduce leakage inductance. The conical connection pipes are machined on to the elements.

Epoxy resin with quartz powder as filler was used as insulator for both elements. Since the force with which the connectors are pressed together might amount to 200 to 300 kg, it was necessary to reinforce the unsupported, long connector pipe. This is done by a brass tube which is put on with a press fit.

The elements are pressed together by a rod in the centre. In order to ensure a good contact, the connection of the single elements is made by means of elastic stainless steel rings, which are slid over the insulated centre rod.

The outer conductor is mainly an aluminium tube with an opening for beam gap and two covers. For the beam gap a special piece was made out of epoxy resin reinforced with glass fibres.

The capacity which is distributed over the length of the kicker magnet unit is made by 0.1 mm aluminium foils which are in contact with the outer conductor and placed between the single elements, which form the inner conductor, with the polyethylene boxes as dielectric. The surface was determined by the capacity, the inner diameter of the ring-shaped condenser plate, by the voltage which is applied, and the opening at the beam gap has to be large enough to prevent secondary particles from causing flashover or breakthrough during operation. All these requirements also fix the outside diameter of the aluminium cladding of the ferrite rings. In order to reduce the electric field strength at the inner circumference of the condenser plate, a brass wire of 0.5 mm diameter was rolled in. Figure 8 shows a complete element with its condenser plate in place before mounting.

Figure 9 shows a kicker magnet unit during the mounting. The elements are stacked into the outer conductor, and in a few steps the unit is impregnated in vacuum with high-vacuum silicon oil and closed vacuum-tight. Since the kicker magnet is operated in vacuum, high-vacuum oil was used for impregnation. The two short pipe pieces which are mounted on the outer conductor allow degasing of the magnet units in the vacuum tank of the PS if necessary.

An expansion reservoir, a spring-loaded bellow, mounted at one end, (the outside) of each kicker magnet unit, is foreseen for the thermal expansion of the oil. The force of the spring is adjusted so that it maintains a pressure between 0.1 to 0.3 kg/cm<sup>2</sup> inside the magnet, keeping residual gas bubbles within a certain size to prevent flashovers between the inner and outer conductors during operation in vacuum.

Figures 10 (a) and 10 (b) show a complete unit.



Two of these units which form the kicker magnet are mounted into a C-shaped support. They are insulated against the support to allow for the kicker magnet circuit to be connected to the ground on a single chosen point. The support is fixed to a travel gear for the horizontal displacement. The movable fixation, which was essential since the vacuum tank and hydraulic actuator have independent foundations, is made by three bearings which give the necessary degree of freedom for disalignment. The travel gear with a stroke of 300 mm, runs on four ball pushings. Up to now  $10^6$  movements, which corresponds approximately to a length of 400 km, with a medium speed of 1 m/sec were made with the same ball pushings. Shaft and ball pushings are still in perfect condition. Since the bearings are operated in vacuum, Apiezon grease was used for greasing.

A block diagram for one kicker magnet unit is given in Fig. 11. For the choice of characteristic impedance of the kicker-magnet circuit, one of the main factors were the coaxial cables which were available on the market. A  $52\ \Omega$  cable designed for 100 kV and not for bulky dimensions seemed to be the best choice. Therefore, for the connection from the pulse generators to the junction box, and from the junction box to the terminating resistor, five cables in parallel are used. For the connection from the junction box to the magnet single unmatched leads, which are compensated to approximately the characteristic impedance of the circuit by means of condensers. The size of the condensers were determined on a model, where their influence on the rise-time of the pulse and reflections were also studied. Value and position of the condensers can be seen in Fig. 11.

The cross-section of a junction box is seen in Fig. 12. These boxes, where the five cables are joined with the flexible one, contain the matching condensers  $3 \times 660\ \text{pF}$  and the stop resistor of  $10\ \Omega$ . The four junction boxes are mounted on to the support of the hydraulic actuator beneath the shaft.

For the connection from the junction box to the shaft, highly flexible cables are used. These are X-ray cables, modified for this

purpose. The modification was necessary, since the mechanical stress due to the movement is considerable and they are used for pulse transmission.

The connection to the shaft is seen in Fig. 13. The matching condensers,  $3 \times 660$  pF, and the connections for the leadthrough and the flexible cable are incorporated in a single piece. The four boxes with guiding piece and distance pieces are assembled tightly in a steel frame. The connectors for the interlocks and monitoring and the screw joint for cooling water are fixed on to the guiding piece. For mechanical reasons cold vulcanizing silicon rubber (Silikon Vergussmasse) was used as insulating material. This silicon rubber was poured in a single working operation into the prepared boxes. In order to prevent flashover at the condenser, the distance between inner and outer conductor is smaller than in the junction boxes, the three condensers,  $3 \times 2000$  pF, 30 kV which are connected in series, are assembled to a single piece which forms a cone similar to the high voltage connectors. The connection to the inner conductor is made by sliding contact, and they are pressed in by means of an O-ring which is placed between the condenser and the cover. To have a good fit of the connectors in direction to the kicker magnet, a pressing device is foreseen for each box which applies a force to the elbow of the connector pipe in the kicker magnet direction.

The leadthrough of all leads from the connection boxes at the shaft to the kicker magnet has to be vacuum-tight. For the pulse transmission to the kicker magnet the four coaxial leads are specially made. The principle can be seen in Fig. 4. The inner conductor is fixed to the insulating Teflon part which can slide in a brass tube, which is the outer conductor. The outer conductor is fixed in a guiding piece, a cylinder of filled epoxy resin. The vacuum joint is made by O-rings. The connectors for the coaxial cable for the field signal, the cylinder of epoxy resin which contains the leads for the interlocks and the copper pipes for the cooling water are also equipped with O-rings and fixed to the guiding piece. The whole assembly can slide in the shaft vacuum-tight.

The inside connection of the magnet units is connected directly to the shaft. The connection to the outside is made by leads which have on the shaft side matching condensers,  $3 \times 660$  pF. One of these leads, partially assembled with its condensers, is shown in Fig. 14. As for the connection on the shaft, the condensers had to be embedded in epoxy resin and shaped to a cone afterwards.

The principle of the high-voltage connectors can be seen in Fig. 4 and Fig. 12. The cone has a taper of  $\sim 3^\circ$ . The contact of the inner and outer conductor is made by a sliding contact which gives contact over the whole circumference. One of the contact parts has spring characteristics, and so a good contact is always given. In order to prevent flashover along the cone surface, a thin layer of high voltage silicon grease is put on the cones and so it fills the space between the male and female part of the connector. The connectors which are inside the vacuum tank are equipped with O-rings in order to prevent air, which stays in the empty space at the end of the connectors when they are assembled, from being pumped out and leaving a path which might cause a flashover between the inner and outer conductors. The same applies to the condensers.

To carry away heat which may be produced by the current in the kicker magnet and in the shaft due to the friction in the vacuum seal, a cooling water circuit is foreseen in the support. For this purpose two holes of 10 mm diameter are drilled into the back of the support and joined at the ends to give a single loop.

Figures 15 (a) and 15 (b) show the kicker magnet above its vacuum tank.

## 5. Monitoring and Interlocks

For the observation of the magnetic field signal, a loop is mounted over the whole length outside the beam gap in the stray field of each unit. This signal also serves as an interlock, such that if the difference of the two signals is greater than a certain preselected percentage over more than

a preselected number of pulses, in a preselected time, the high voltage supply is switched off.

The position of the expansion reservoir (bellow), and so the pressure in the kicker magnet, is measured by a linear potentiometer which displays the exact position on a meter. The sliding contact is fixed to the bellow of the expansion reservoir and the housing to the kicker magnet unit. With a resistance of  $40\text{ k}\Omega$  it gives a resolution of  $0.1\text{ mm}$ . Two switches are foreseen for the maximum and minimum position.

To have a relative check on the temperature of the kicker magnet a resistance thermometer is mounted in the support. This signal also serves as an interlock.

In order to prevent the kicker magnet from being hit by the beam, and consequent damage of the insulation, a so-called 'beam razor' is mounted at the downstream end of the magnet. The 'beam razor' is a fork which extends  $80\text{ mm}$  from the centre of the beam gap further out in a radial direction, and has an opening of  $11\text{ mm}$  at its ends, compared to  $15\text{ mm}$  of the beam gap. If the beam were to blow up, or vertical oscillation were to occur, the part of the beam which lies outside of  $11\text{ mm}$  is shaved off, so when the kicker magnet is brought around the beam its diameter is hoped to be maximal  $11\text{ mm}$ .

The position of the beam in the horizontal plane is not as critical, since there is more margin.

## 6. Tests

Before a decision was taken concerning the insulating material for the boxes into which the single elements are placed, different types were tested with DC. Out of the selected material boxes were made and in the same configuration of outer conductor, inner conductor and condenser plate as in the kicker magnet, extensive tests started. During these tests the influence of the wire diameter, which is enrolled in the inner circumference

of the condenser plate, on the breakdown voltage was studied for diameters from 0.1 to 0.8 mm. These tests were performed with DC and pulsed voltages up to 70 kV in order to give a limit for the lifetime. With 55 kV,  $1.5 \cdot 10^6$  pulses were made without breakdown on five boxes.

Before assembling, all parts which were exposed to high voltage were tested with 60 kV DC for several hours.

After these tests a complete assembly (pulse generators, cables, kicker magnet and terminating resistor) was made and tested.

The next step was the testing of a complete assembly under working conditions, except radiation. This means in vacuum and with movement. Under this condition  $2.5 \cdot 10^5$  pulses were made at 70 kV on the storage lines. At the beginning of this test a flashover occurred along one connection cone on the kicker magnet at 40 kV on the storage line. Putting O-rings on the cones, as can be seen in Fig. 5, solved the problem.

## 7. Measurements

### 7 (i) Measurement of the characteristic impedance of the kicker magnet unit.

After having assembled the first kicker magnet unit, its impedance was measured in order to check the calculation and, if necessary, change the capacity of the units by changing the surface of the condenser plates which are placed between the elements. To study its characteristics the kicker magnet unit was terminated by a precision resistor charged to a voltage of 30 V and discharged by means of a mercury switch which has a switching time of few ns. The pulse shaped at the terminating resistor was observed with an oscilloscope. The impedance was found by changing the terminating resistor until the reflections were zero, and according to  $r = \frac{Z_t - Z_0}{Z_t + Z_0}$  this is the case if the impedance of the kicker magnet unit is equal to the terminating resistor. The first measurement has given an impedance which was 5% too high, and in order to compensate it, the capacity of the unit was revised accordingly.

7 (ii) Measurement of the magnetic field

The magnetic field versus the voltage on the storage line was measured up to 70 kV; this is 35 kV on the kicker magnet, in the centre of the beam gap. Further, the field distribution was measured in axial and radial directions at 60 kV on the storage lines. For the measurement of the magnetic field and its radial distribution, a loop over the total length of the kicker magnet and 1 mm width, and for the axial distribution a small loop of 5 mm length and 1 mm width, was used. The loops could be moved in a radial and axial direction, respectively. The signal was integrated by means of an appropriate RC element, displayed on an oscilloscope and compensated by a DC voltage, which was measured with a digital voltmeter. The magnetic flux density was evaluated from the measured voltage. The accuracy which could be obtained was  $\pm 1\%$ .

The kick as a function of the voltage on the storage line is shown in Fig. 16. This nomogram also gives the beam displacement in mm at the ejection magnet for different momentum. The radial distribution is shown in Fig. 17.

7 (iii) Measurement of the kicked beam position

A scintillation screen which is mounted on the upstream end of the ejection magnet, and which can be seen by a television camera, permits the position of the undisturbed and the displaced beam to be checked. The scintillation screen has a graduation of 5 mm and hence it gives the possibility of having a check of the beam displacement. The results obtained agree with the results given in Fig. 16.

8 First results

The operation of the fast-ejection system proved that the kicker magnet has worked as foreseen. The kick which was obtained allowed from  
PS/4631

the beginning an efficiency of 95%. Out of 20 bunches one was lost. With some improvements on the matching of the two storage lines, 100% efficiency was achieved. It was also possible to eject one single bunch, without too much perturbing the other 19 bunches. Figure 19 shows the field signal for total beam ejection.

Up to now,  $10^6$  pulses were made at 48 kV on the storage line. This corresponds to a momentum of 24.8 GeV/c of the ejected beam. One magnet unit was changed after  $0.8 \cdot 10^6$  pulses in order to check its state.

The behaviour of the kicker magnet under radiation is not yet completely clear. Owing to the radiation, when the beam, due to oscillations, was hitting the kicker magnet, gas was developed in the kicker magnet, the pressure rose to  $0.3 \text{ kg/cm}^2$ , and it was necessary to de-gas it after 50,000 - 70,000 pulses, for 2 hours. With a stable beam and stable operation it was possible to operate the system continuously for 5 days, this corresponds to  $1.4 \times 10^5$  pulses, without appreciable gas development.

The unit which was demounted after  $0.8 \cdot 10^6$  pulses showed traces of flash-over or corona near the beam gap. The current in these flashovers must have been small, since there was no visible change in the pulse shape, and also the interlock, which would have detected a difference of approximately 5% between the pulses of the two units, showed no fault.

Radiation tests will be performed on samples of silicon oil and polyethylene to study this problem.

As a first measure, a signal given by a radiation monitor when the kicker magnet is intercepting the beam, will be used to give an acoustic signal, in order to prevent the kicker magnet from being unnecessarily irradiated.

The operation of the kicker magnet was satisfactory, except for the problem which arose with the radiation. A limit for the lifetime cannot yet be predicted, but it certainly will be of the order of a few million pulses.

9. Acknowledgements

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S. Pichler

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References

- 1) B. Kuiper, G. Plass - On the fast extraction of particles from a 25 GeV Proton Synchrotron, CERN 59-30, 24th August 1959.
- 2) R. Bertolotto et al - The fast ejection system of the CERN 25 GeV Proton Synchrotron, NPA/Int. 63-15 (Paper submitted to the International Conference on High Energy Acceleration held at Dubna 21-29 August 1963).
- 3) R. Bertolotto et al. - The extracted 25 GeV/c Proton beam for the CERN neutrino (Paper submitted to the International Conference at Sienna from 30th Sept. to 5th Oct. 1963).
- 4) The pulse generators of the CPS - fast ejection system, NPA/Int. (to be published).
- 5) The monitoring and interlock system of the CPS-fast ejection system, NPA/Int. (to be published).
- 6) G.K. O'Neil and V. Korenman - The delay time inflector - Princeton Pennsylvania Accelerator project, GKON 10, VK 13, 18th Dec., 1957.
- 7) CERN, CPS-User's Handbook.

TABLE 1

Gap height	( ferrite	22 mm
	( useful for the beam	15 mm
Gap width	( ferrite	32 mm
	( useful for the beam	25 mm
Length		450 mm
Ferrite length		280 mm
Number of ferrite rings		17
Number of elements		18
Delay-time		0.07 $\mu$ sec
Inductance		0.7 $\mu$ H
Capacitance		6600 pF
Impedance		10.4 $\Omega$
Max* kicker voltage		35 kV
" current		3360 A
" magnetic energy		9.3 J
" electrostatic energy		9.3 J
" mag. field density		0.17 Wb/m <sup>2</sup>
" mag. field density in the ferrite		0.3 Wb/m <sup>2</sup>
Pulse duration		2.1 $\mu$ sec
Pulse duration for single bunch ejection		0.1 $\mu$ sec
Number of units for the kicker magnet		2
Max. kick in the entire magnet		0.15 Wb/m
* used over at least 10 <sup>6</sup> pulses		
Pulse transmission cable		
Impedance		52 $\Omega$ (5 in parallel)
Max. operating voltage		100 kV

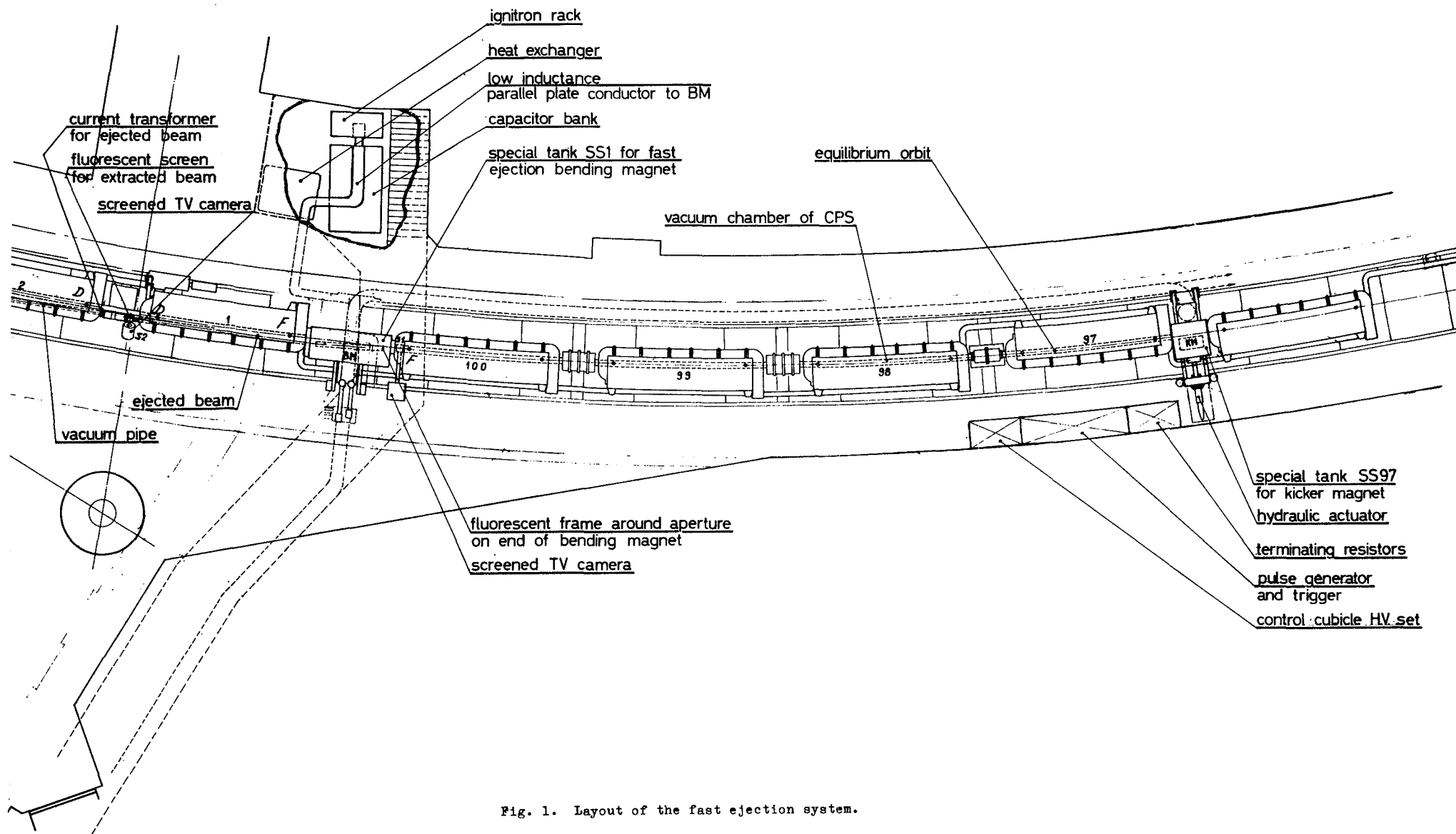


Fig. 1. Layout of the fast ejection system.

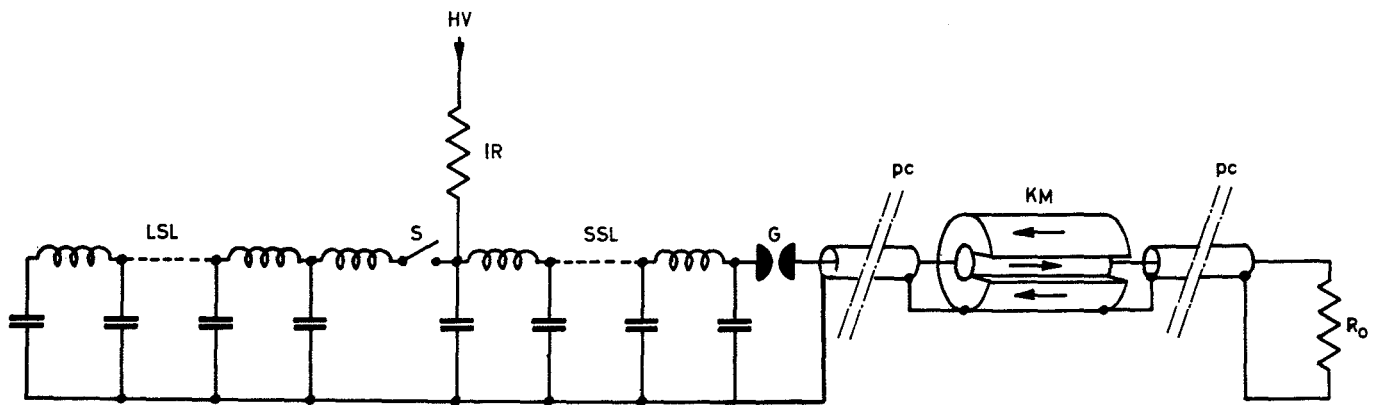


Fig. 2 Principle of the kicker magnet circuit. HV = charging line from high voltage set ; IR = isolating resistor ; LSL = long storage line ; S = switch (when closed: 2  $\mu$ s pulse; when open: 100 ns pulse); SSL = short storage line; G = sparkgap; pc = pulse cables; KM = kicker magnet; R = matched terminating resistors.

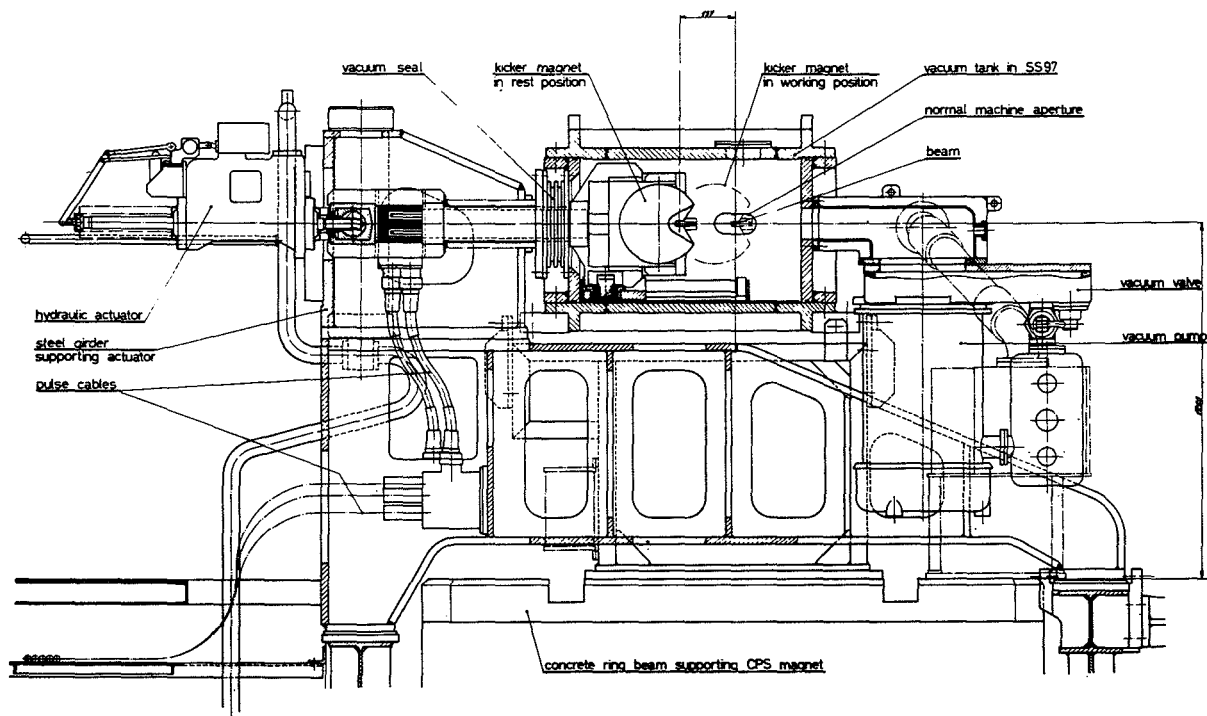
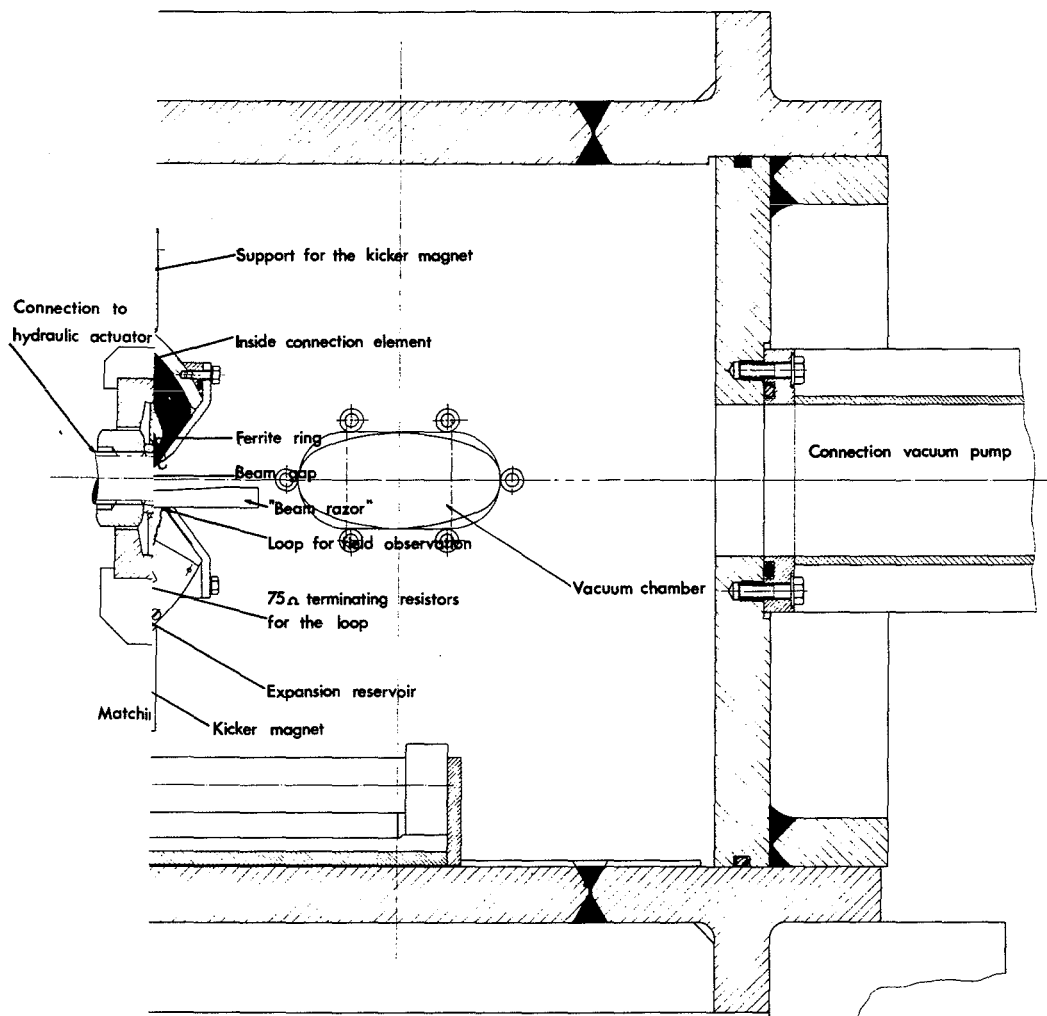
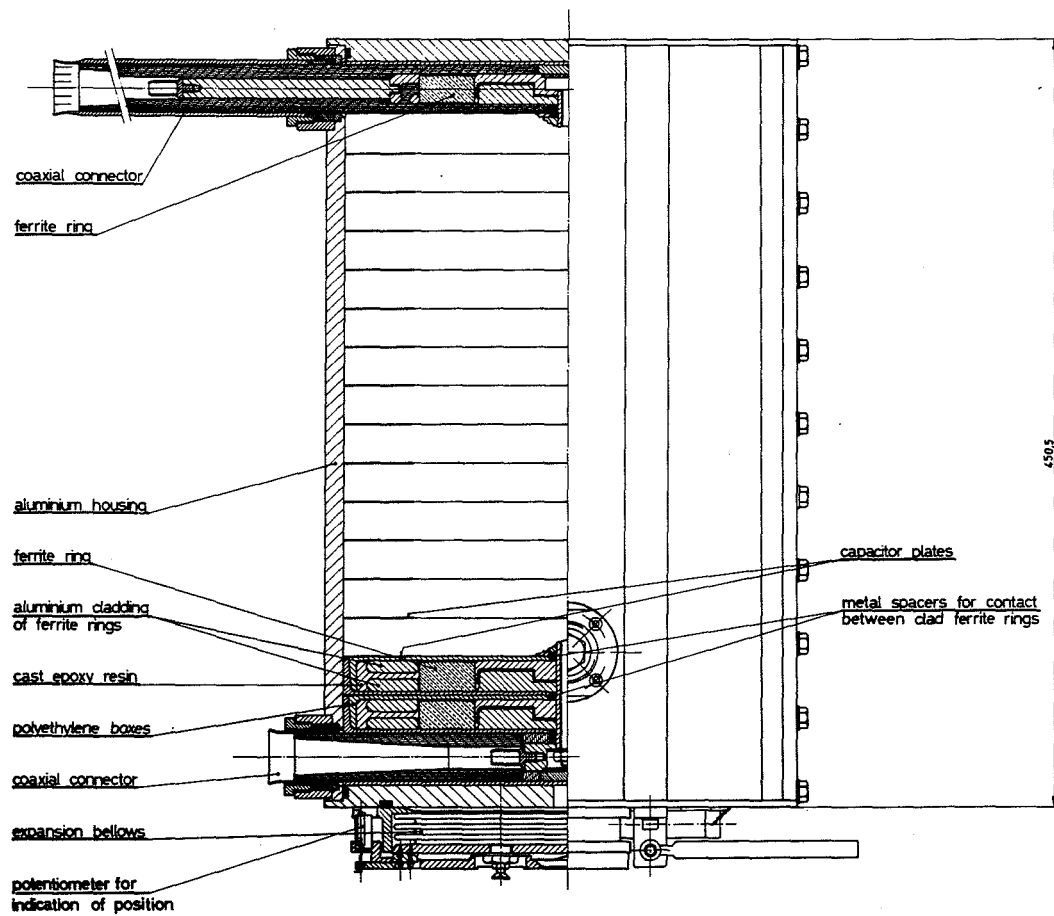
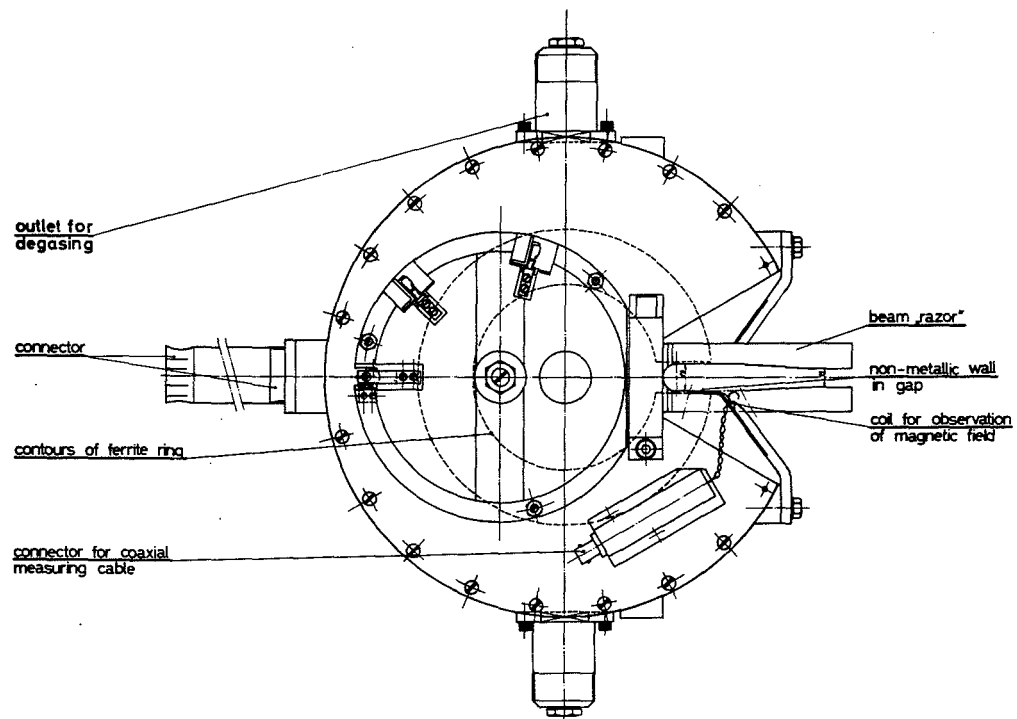


Fig. 3 Sectional view of the kicker magnet in its vacuum tank.





**Fig.5. STRUCTURE OF A KICKER MAGNET UNIT**

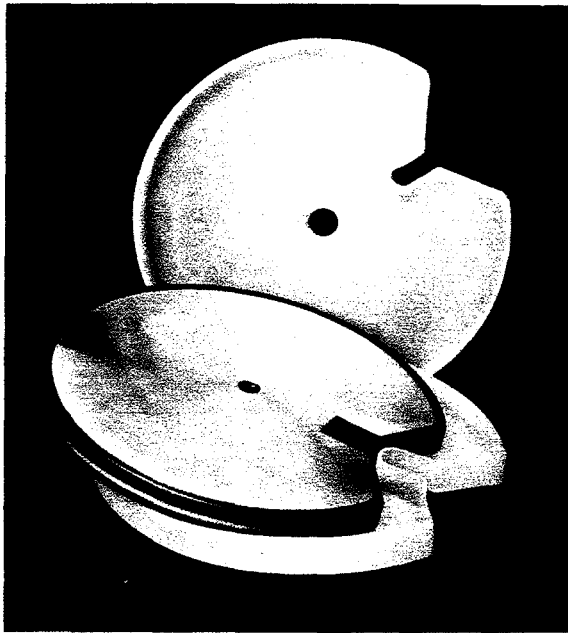


Fig. 6

Aluminium-cladded ferrite ring with polyethylene box

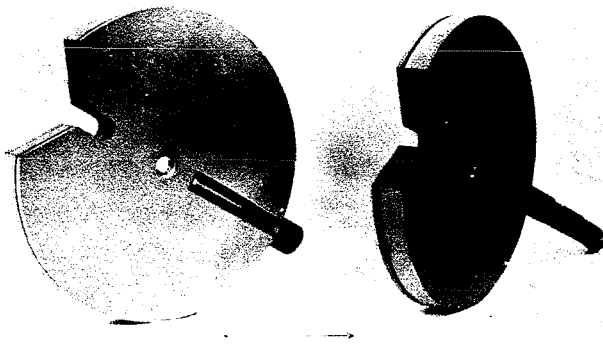


Fig. 7

Connection elements

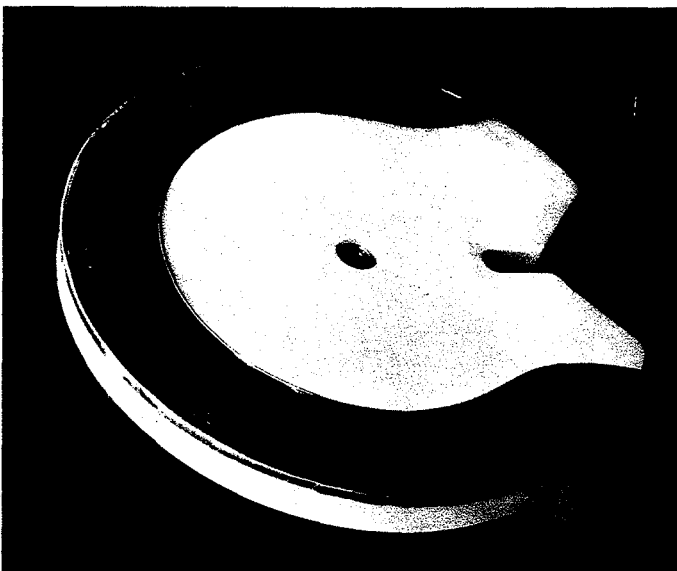


Fig. 8

Complete element before mounting

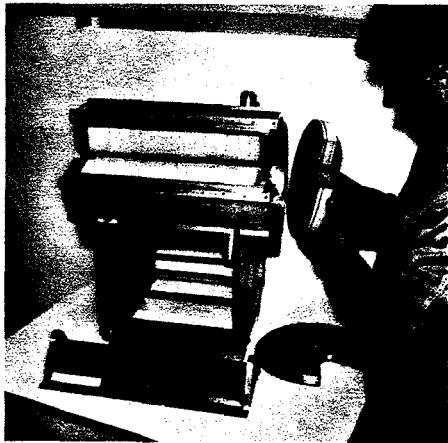


Fig. 9

Kicker magnet unit are being mounted. The connection element is put in place

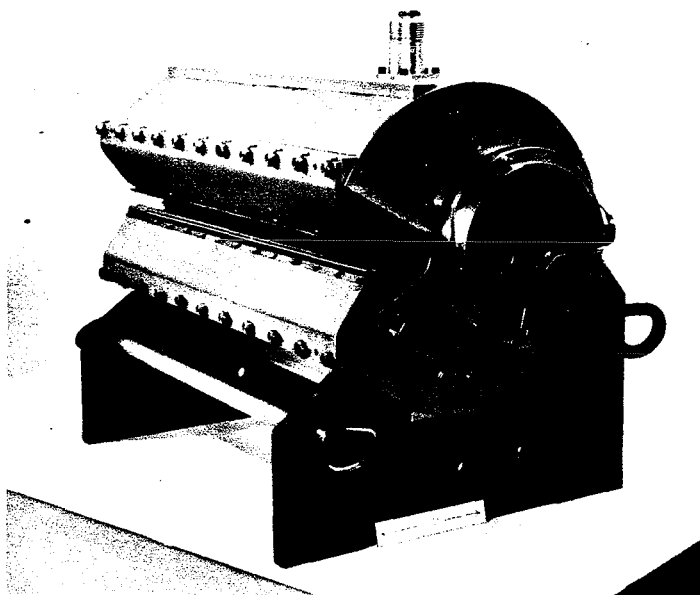


Fig. 10 a      Finished kicker magnet unit

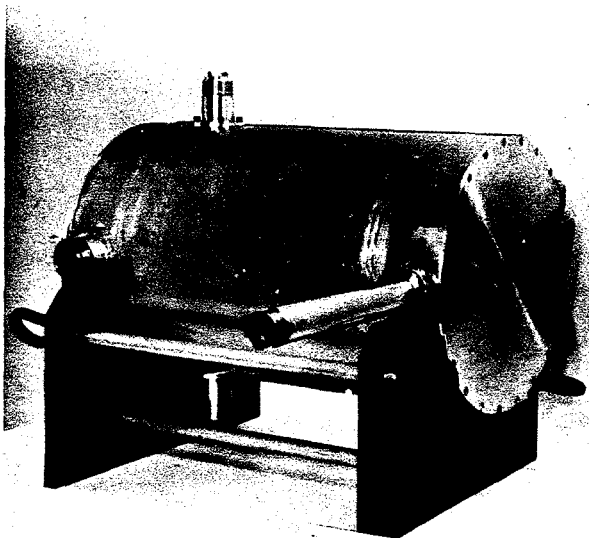


Fig. 10 b



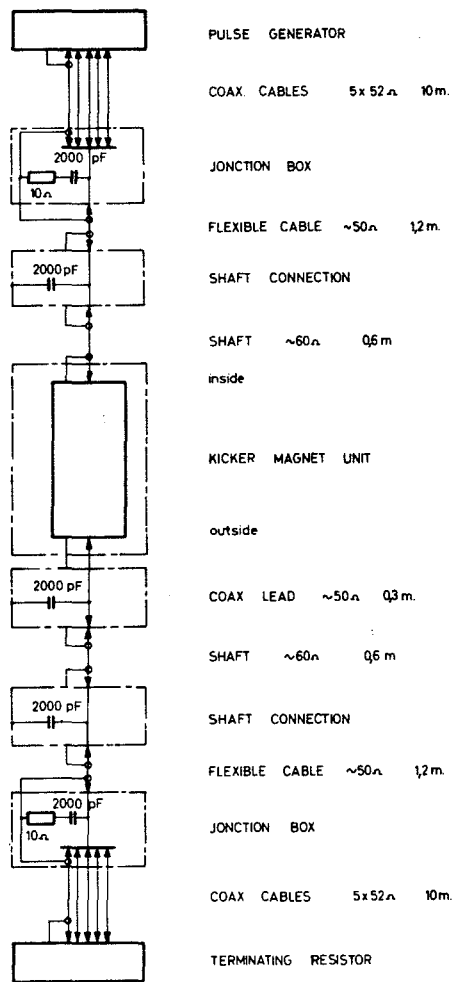


Fig.11- Block diagram of a kicker magnet unit.

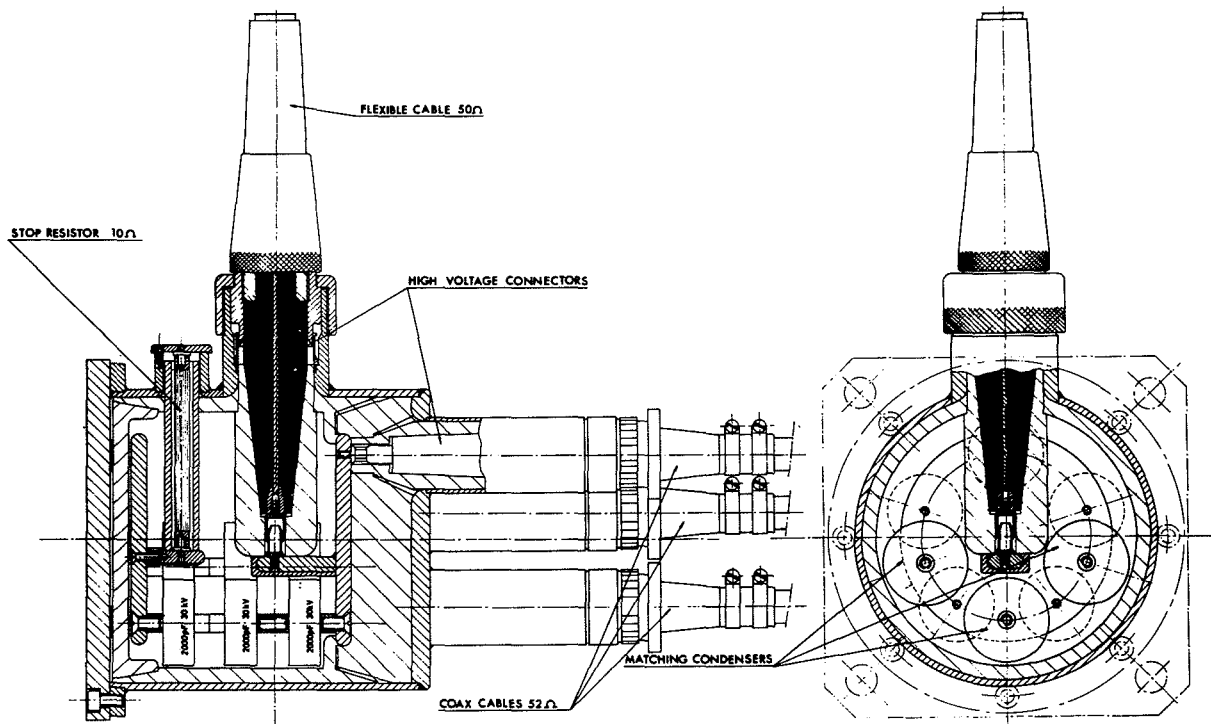
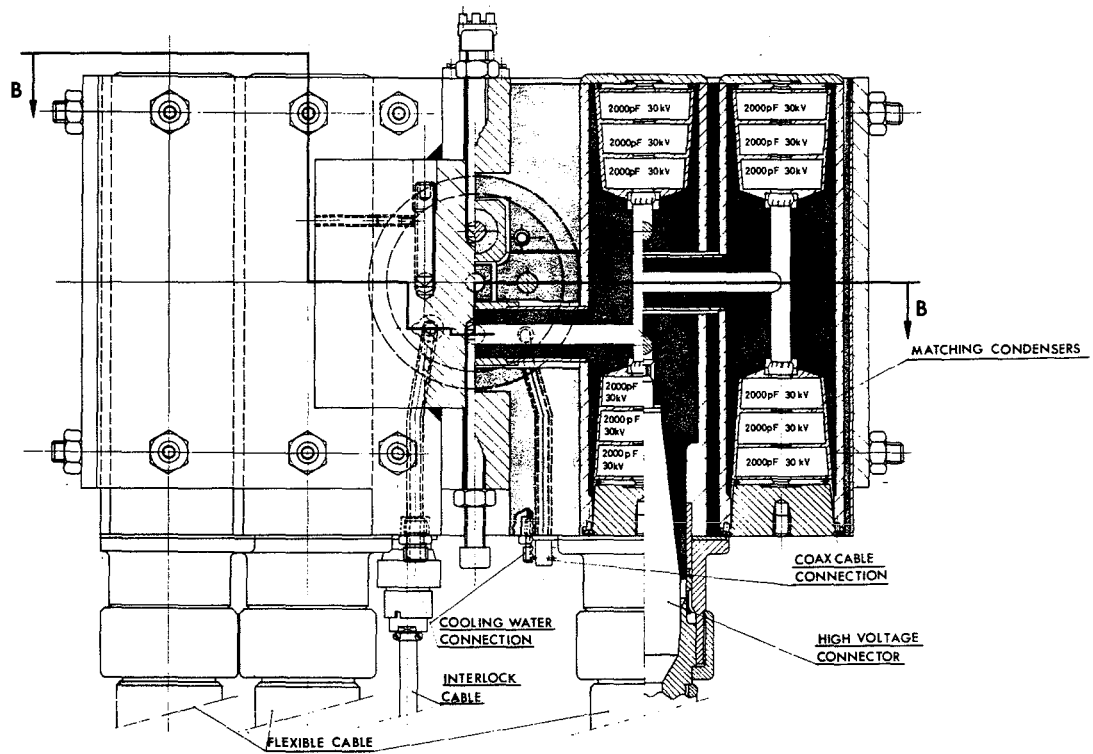
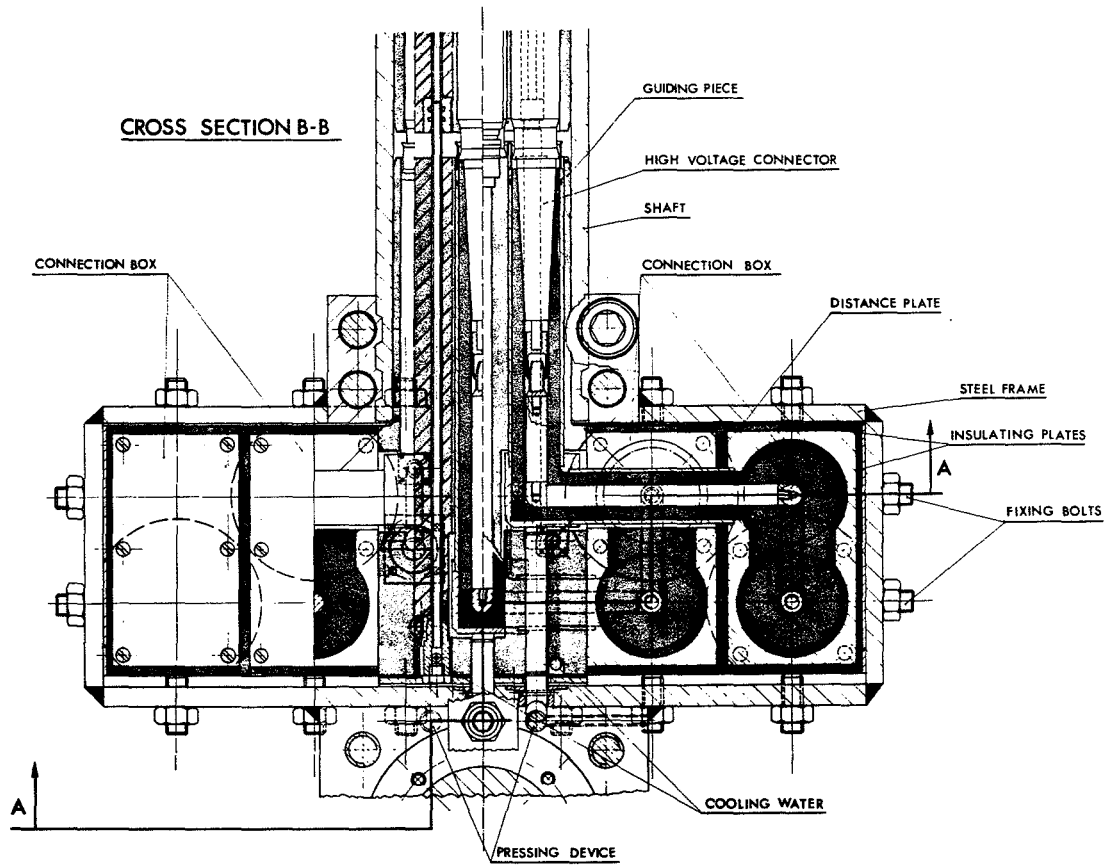


Fig.12 JUNCTION BOX

# CROSS SECTION A-A



# CROSS SECTION B-B



**Fig:13 SHAFT CONNECTION**

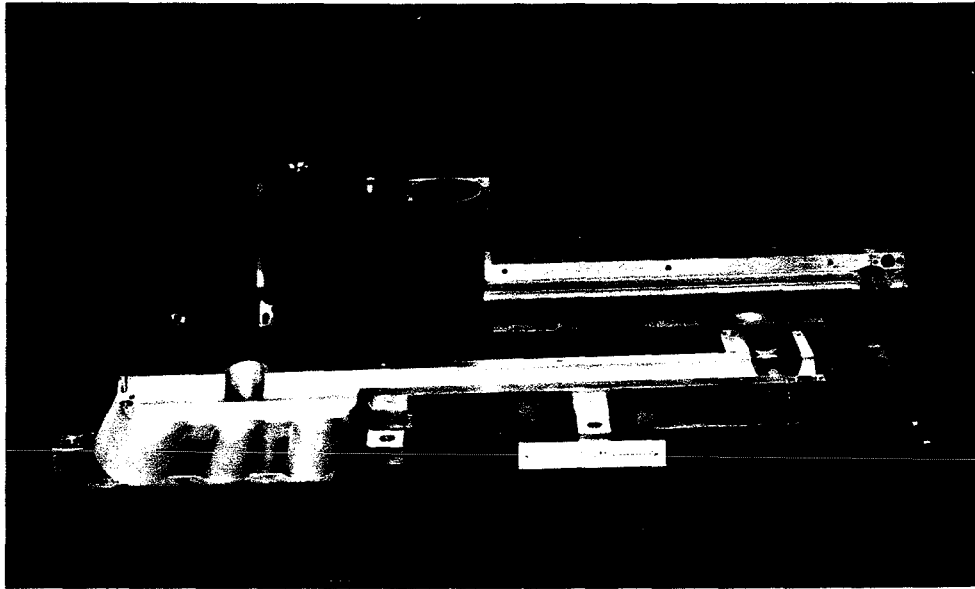


Fig. 14      Coaxial lead with matching condensers

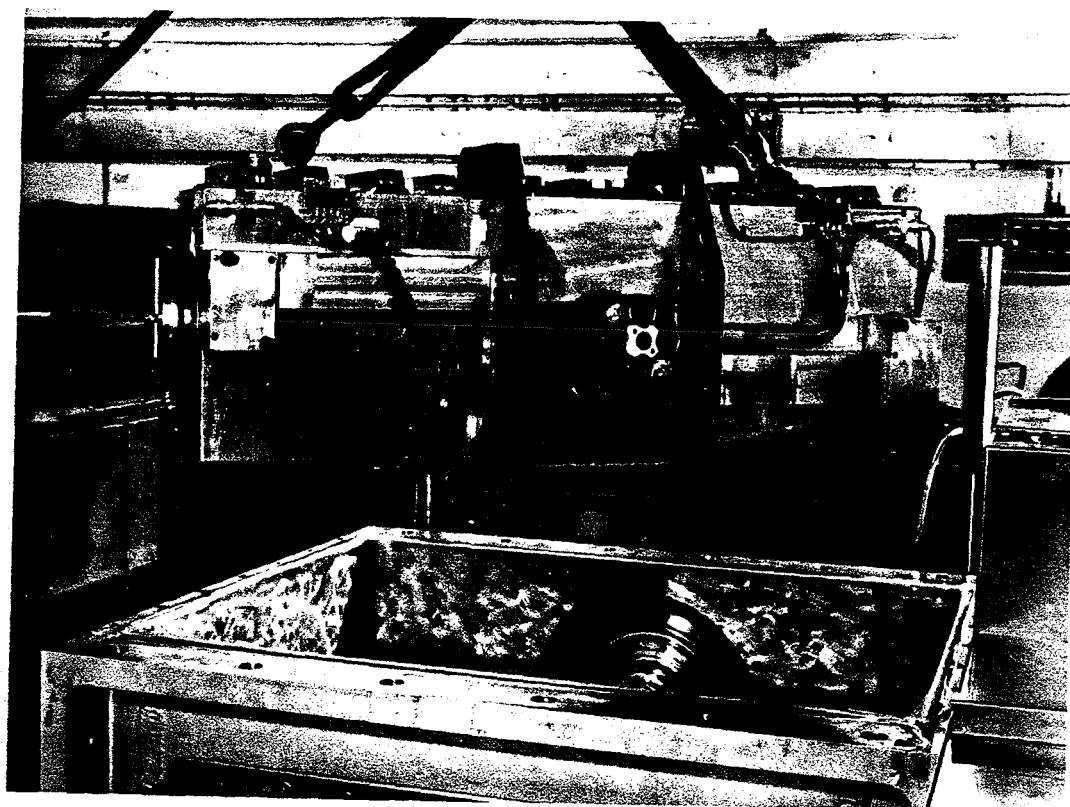
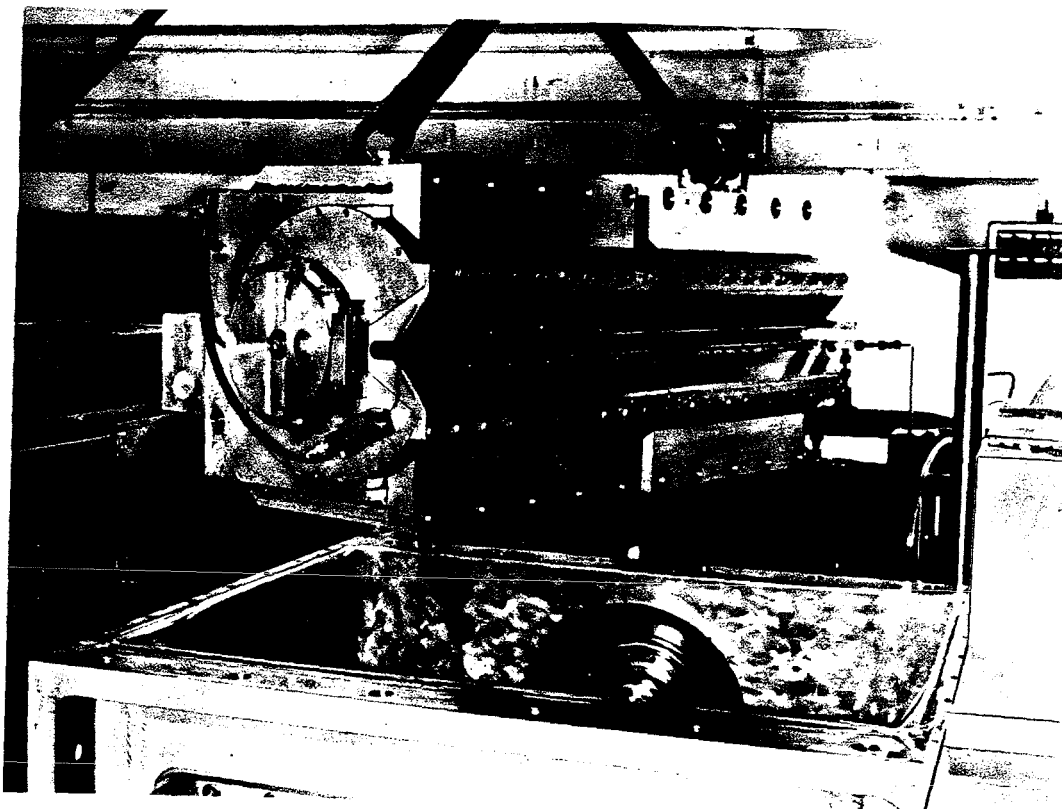


Fig. 15 a / b Assembled kicker magnet above its vacuum tank

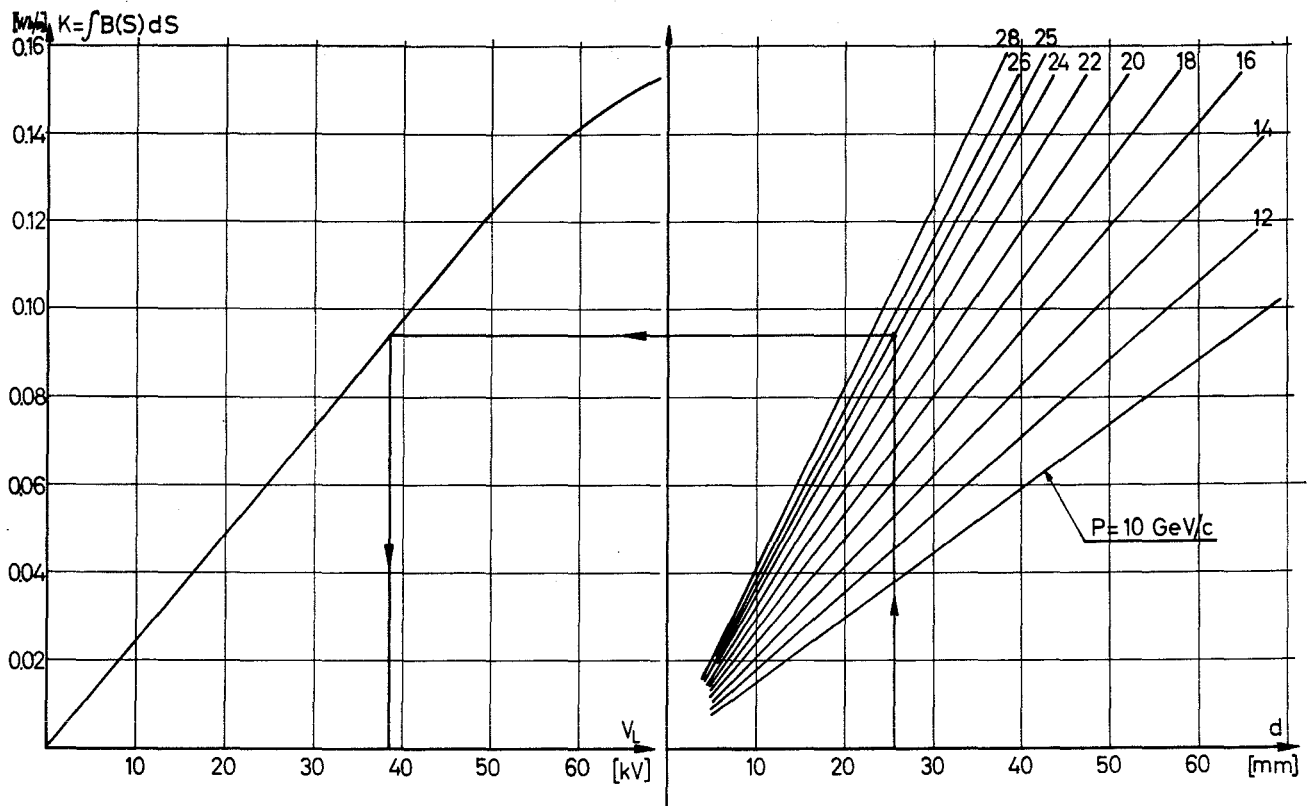


Fig. 16 Magnetization curve of the kicker magnet. Kick  $K$  as a function of the line voltage  $V_L$ . The nomogram gives the relation between the line voltage, the proton momentum  $p$  and the radial displacement of the beam at the bending magnet.

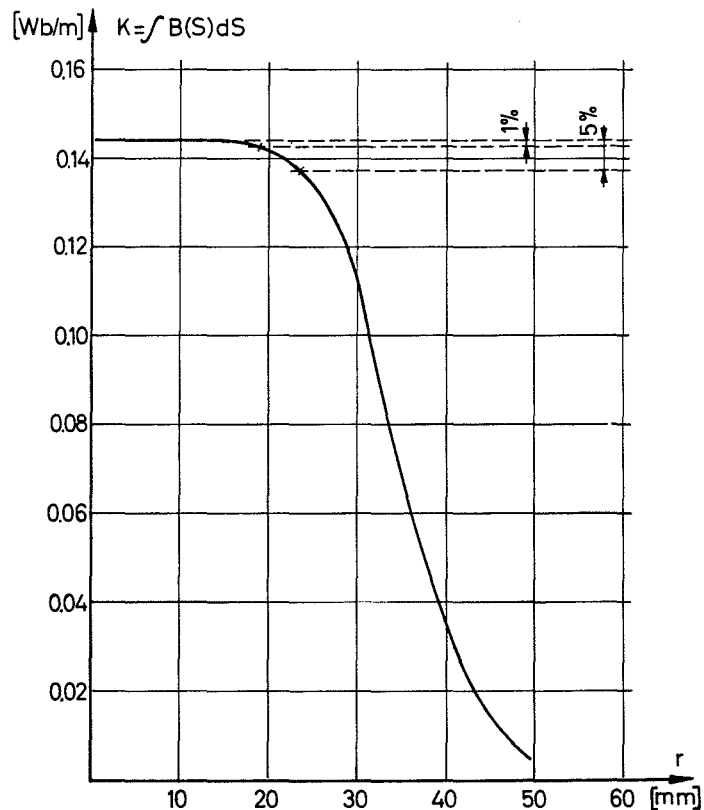
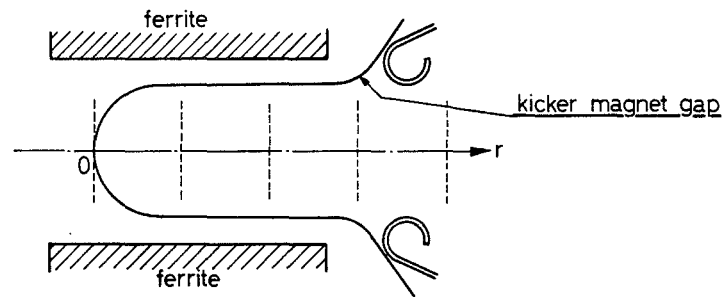


Fig. 17 The kick  $K$  as a function of the radial position in the gap of the kicker magnet.

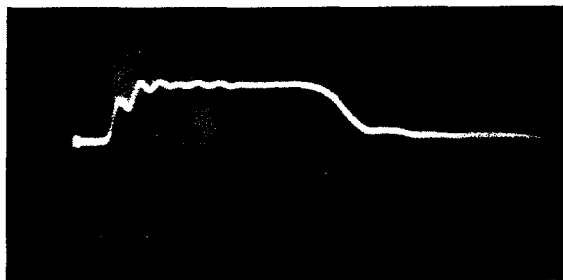


Fig. 18 Sum of magnetic kicks in the two kicker magnet units. Each derived from a loop through the entire length of the unit. Sweep:  $0.5 \mu\text{s}/\text{div}$ .